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JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM (JTIDS).

STANDARD SYMBOLOGY, PHASE I

COCKPIT DISPLAY PRESENTATION FORMATS AND FLIGHT TEST SYMBOL SET.

Part I,

Standard Symbology Study

Appendix A — Surveyed Organizations.

Appendix B - Documents Surveyed.

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LEGIBILITY	OPERATOR FATIGUE	FONT	RESOLUTION
BRIGHTNESS	DISPLAY CLUTTER	STROKE	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The proliferation of symbology for Electro-Optical (E-O) displays used in aircraft is a continuing problem. The Symbology Standardization Committee was established to derive a single set of standard symbols for Air Force aircraft JTIDS displays. This report documents the Phase I effort, "Paper Study & Analysis" of the committee and contains the symbol set recommendations and associated hardware requirements necessary for the JTIDS flight test. The Phase II effort, "Simulation and Flight Test", will involve extensive investigation of proposed symbols in order to establish a military standard for JTIDS.

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CONT'D:

4. PART I
   STANDARD SYMBOLOGY STUDY
   APPENDIX A - SURVEYED ORGANIZATIONS
   APPENDIX B - DOCUMENTS SURVEYED

FOREWORD

This document is the result of a six-month study in support of the Joint Tactical Information Distribution System (JTIDS) Avionics Management Office of ASD/AES. The work effort was accomplished by using the JTIDS Symbology Standardization Committee, an organization which originated at Wright-Patterson AFB, Ohio. Active committee members include: Mr. Harry Waruszewski (ASD/ENAIC), Chairman; Mr. James Casella (ASD/ENAIC); Major John Churchwell (ASD/AES, ENACB); Ms. Frances Kniess (ASD/ENECC); Dr. John Reising (AFFDL/FGR); and Mr. William Pearson (AMRL/HEB). The task was accomplished under Project #2283 of Program Element 64754F.

This report includes work performed between 10 May 1976 and 30 October 1976.

Appendix "C" is classified and is bound separately and identified as Part II of this report.

This report has been reviewed and is approved.

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INTRODUCTION

1. INFORMATION REQUIREMENTS.

The Joint Tactical Information Distribution System (JTIDS) is a digital, secure, jam-resistant, communication system for real-time command and control of combat operations. The system uses Time Division Multiple Access (TDMA) to interconnect all system participants into one common channel, or network, for distribution of information. In August 1975, the Tactical Fighter Weapons Center (TFWC), Nellis Air Force Base, Nevada, was tasked by TAC/DR (confidential message 081330Z Aug 75) to study and recommend essential JTIDS information requirements for fighter aircraft and resulted in "USAFTFWC JTIDS Information Requirements Study (September 1975)." Aeronautical Systems Division, Deputy for Aeronautical Equipment, Directorate of Avionics Standardization and Systems Architecture (ASD/AES) and Deputy for Engineering, Directorate of Avionics Engineering (ASD/ENA) both at Wright-Patterson Air Force Base, Ohio (WPAFB), used the TFWC study to derive a set of information requirements which are common across the major tactical missions and incorporated it into "Information Presentation and Control Concept for JTIDS in a Single Seat Tactical Aircraft - Part I: Analysis of TFWC JTIDS Information Requirements and Part II: Implementation and Data Management." This effort uses the above studies as the information baseline to establish and develop the flight test symbol set.

2. SYMBOLOGY STANDARDIZATION COMMITTEE.

Results of previous preliminary studies by DoD organizations and contractors indicated that additional work in the symbology area was necessary with JTIDS symbology standardization having an immediate need. Symbology standardization will avoid the current symbol proliferation trend by which contractors introduce their preferred symbol set with each contract aircraft. ASD/AES has responsibility for standardizing JTIDS symbols since

avionic standardization (common avionics, displays, controls, etc.) is presently being performed by that organization.

In April 1976, a Symbology Standardization Committee (SSC) was formed at WPAFB, Ohio, to deal with the presentation of the added information available through JTIDS. This committee was comprised of the following Wright-Patterson AFB organizations:

ASD/AES	AFFDL
ASD/ENA	AMRL
ASD/ENE	AFAL

The JTIDS Standard Symbology Schedule, Figure 1, is divided into Phase I and Phase II. Phase I participating organizations are shown above; however, direct involvement of other DoD organizations will be necessary in Phase II in order to assure successful completion.

The objective of this effort was to determine a JTIDS flight test symbol set with specifications and to provide direction for display management/presentation format for said flight test. Primary emphasis is on symbology definition as predicted for a 1978 time frame.

JTIDS STANDARD SYMBOLOGY SCHEDULE OF EVENTS

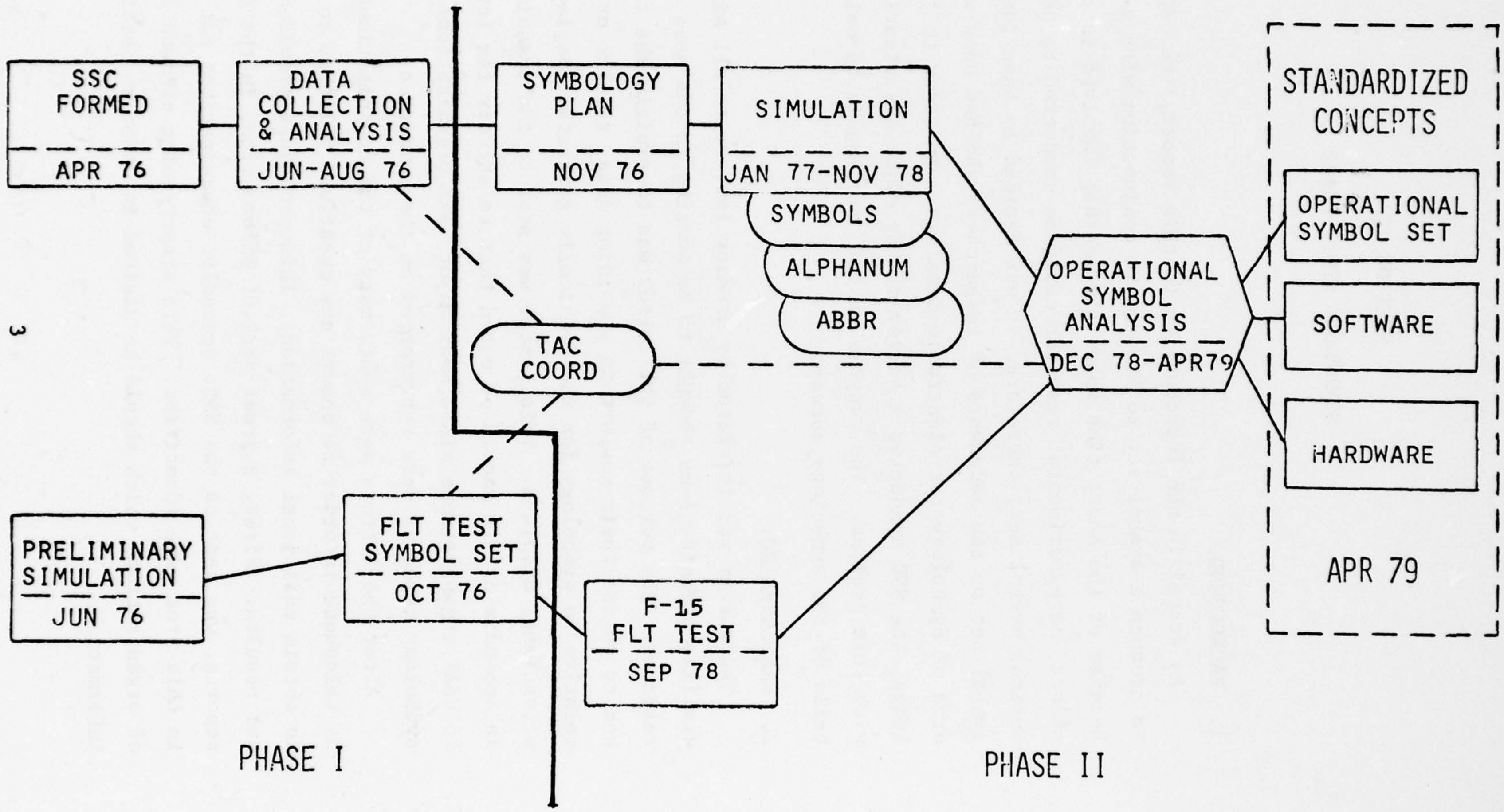


Figure 1

SECTION II

SYMBOLOGY STUDY PHASE I

1. BACKGROUND.

As stated in the Introduction to this report, the SSC was formed to produce a symbol set to be used in conjunction with a JTIDS display. Because of the short time span (six months) involved in the Phase I effort, no experimental research could be conducted to determine an optimal symbol set; therefore, it was decided to base the recommended symbol set on the judgments of researchers who had been working in the area of symbology for electronic displays. In order to tap this knowledge, the SSC conducted a survey of the major organizations concerned with this problem. The purpose of this section is to delineate the details of the symbology survey.

2. PRESCREENING.

The survey was initiated by sending letters to all military and civilian organizations thought to be working in the area of symbology research. The purpose of the letter was to explain the tasks of the SSC and to enlist their support in providing data, reports or information relative to symbology for electronically generated displays, especially situational displays. This letter was sent to the organizations listed in Appendix A. It should be noted that relatively few letters were sent to USAF organizations since most major USAF organizations dealing with symbology research were represented on the committee.

After the letters were sent, many of the organizations were contacted by telephone in order to answer any questions relative to the letter and to obtain additional information. This procedure provided two very useful results. First, a great deal of information, in the form of research reports, was sent to the SSC; secondly, organizations not performing work in this area were identified. This prescreening allowed identification of organizations which should be visited in order to obtain additional information.

3. ORGANIZATIONS VISITED.

Based upon the prescreening, the SSC identified certain organizations for follow-up visits. The decision whether or not to visit a particular installation was determined by; (1) The active programs being conducted; (2) the ability of the SSC members to obtain additional information from examining dynamic symbology on actual displays, and (3) personal contact to discuss classified programs. The following organizations were chosen for visits:

Collins Radio Group
Cedar Rapids, Iowa

Honeywell
Minneapolis, Minnesota

Boeing Aircraft Co.
Seattle, Washington

Grumman
Long Island, New York

Loral
New York, New York

Picatinny Arsenal
Dover, New Jersey

American Institute of Research (AIR)
Bedford, Massachusetts

Mitre Corporation
Boston, Massachusetts

U.S. Army Electronic Command
Fort Monmouth, New Jersey

Aberdeen Proving Ground
Aberdeen, Maryland

Lear Siegler
Grand Rapids, Michigan

Hughes Aircraft
Culver City, California

Pacific Missile Test Center
Point Mugu, California

Naval Air Development Center
Warminister, Pennsylvania

Naval Air Test Center
Patuxent River, Maryland

McDonnell Aircraft Company
St. Louis, Missouri

Kaiser Aerospace
Palo Alto, California

Naval Weapons Center
China Lake, California

4. INFORMATION OBTAINED.

The survey yielded 130 documents (see Appendix B) relevant to the design and formatting of symbology. These documents were used to form a library of information on symbology. This information covered systems such as USAF's F-15, F-16, AWACS and JSS; Navy's F-14, S3A, E-2C, and NTDS; and Army's TACFIRE, resulting in a fairly comprehensive data base for the SSC to evaluate. Although the survey was not exhaustive, the SSC felt that the symbology data base obtained was representative and adequate for the Committee's purpose, given the time constraints imposed upon the work effort.

5. COMMITTEE OPERATION.

The following plan was used to generate the JTIDS flight test symbology:

a. Assign each SSC member a given number of symbology requirements as listed in "Information Presentation and Control Concept for JTIDS in Single Seat Tactical Aircraft", Part I, Annex A, dated April 1976.

b. Research the library for all possible information and symbols used to represent his/her assigned symbol.

c. Present his/her findings and recommendations for the assigned symbols.

d. Discuss recommended symbols, revise as necessary, and vote upon the proposed symbol until acceptance is reached. Acceptance required a two-thirds majority vote.

SECTION III

RESULTS OF SYMBOLOGY STUDY PHASE I

1. SYMBOLS.

a. Font:

Most conventional fonts of alphanumeric characters can be read with reasonable accuracy under normal conditions where size, illumination, and time permit. There are, however, significant differences in the legibility and readability of different fonts where viewing conditions are adverse, time is critical, and accuracy is important. The Navy Aeronautical Medical Equipment Laboratory (NAMEL) font from MIL-M-18012B has been widely tested and found satisfactory and the SSC recommends NAMEL for the alphanumerics on the JTIDS display.

b. Size:

The probability of detecting a target depends upon its size. When determining character size, many factors must be considered. Some of these are: brightness, search time, contrast, operator fatigue, display clutter, criticality of the data, and conventionalism of the symbol. The critical factors for determining minimum size are probability of recognition and reaction time. Traditionally, the minimum size recommended was based upon clearly printed characters with good contrast and brightness, good (20-20) eyesight, with no consideration given to fatigue, visual, or system anomalies. Thus, most of the data is based upon an ideal situation and may be an underestimate of requirements.

Other factors to be considered in determining recommended character sizes are the display clutter and the importance of the data. An increase in size is often used to emphasize important data in the display. Another reason to increase the size of a symbol is because the operator's reaction time to the symbol is too long, or the probability of detection is low. Symbols can, of course, be made too large and in this case display clutter will put an upper limit on desired character size.

In view of the proposed set for JTIDS, clutter has a significant effect on our decision for symbol size. It is also difficult to define the exact point at which clutter becomes objectionable due to its subjectivity.

To calculate the size of a character on a display, the following formula is used:

$$H = 2D \tan\left(\frac{\theta}{2 \times 60}\right)$$

Where D = Viewing distance in inches from design eye to display surface

θ = Minutes of visual angle

H = Height of symbol in inches

EXAMPLE: The symbol "A" subtends 17' of visual angle and viewing distance is 28"

From this: $\theta = 17'$

D = 28"

$$\text{Height of "A"} = 2\,(28) \times \tan\left(\frac{17}{2 \times 60}\right) = 0.1385 \text{ inches}$$

So, the height of "A" is 0.139" when the display is viewed from 28"

When the visual angle subtended by the largest dimension of the target is smaller than twelve minutes, an increase has been shown (Ref. 1) in relative search-to-identification time and in errors of identification. This indicates that targets should subtend, as a minimum, 12 minutes of arc to insure reasonably accurate recognition. Other studies conducted by human factors personnel have shown the visual angle subtended should be 15 minutes and some studies have recommended as high as 20-25 minutes.

Given the conditions under which the pilot will be viewing the JTIDS display and given that the viewing distance from the pilot's eye to the JTIDS display is unknown at this time, it is more reasonable to specify a minimum visual angle subtended at the eye by the character rather than a minimum character size. Based on research done and discussions held with human factors personnel, the SSC recommends that the largest dimension of a symbol be no less than 17 minutes of visual angle.

The symbol set of Appendix C in Part II gives the height and width dimensions in minutes of visual angle.

c. Symbol Legibility:

Size is only one of the factors which affect the legibility of alphanumerics. Another of these is the aspect ratio. Although a square (1:1) character can be read, the SSC recommends an aspect ratio of 3:2, height to width.

d. Stroke Versus Raster:

Another factor affecting size and legibility is in the technique of symbol presentation. A raster generated symbol has basically three problems associated with it:

(1) The symbol is made up of raster lines and/or dot/dashes on a horizontal line. Rotation of raster symbols causes discontinuities of the symbol and, therefore, the symbols must be made larger to retain legibility during rotation. Discontinuity of lines occurs at shallow angles to horizontal and is cosmetically undesirable. Raster symbology also lacks in crispness.

(2) When a raster symbol is written, one-half of the symbol is written every one-thirtieth of a second. This basically is a refresh rate of 30 times a second. Although not immediately unpleasing to the eye, it will induce fatigue more rapidly than a refresh rate of 50 times a second. Under certain lighting conditions, a hint of flicker can be seen.

(3) Due to the writing speed required for a raster display, the symbology will be dimmer (i.e., less contrast) unless the beam power is increased. On any given CRT, a stroke symbol written at the slower speed will have much more contrast than a raster symbol operating at the beam power limit.

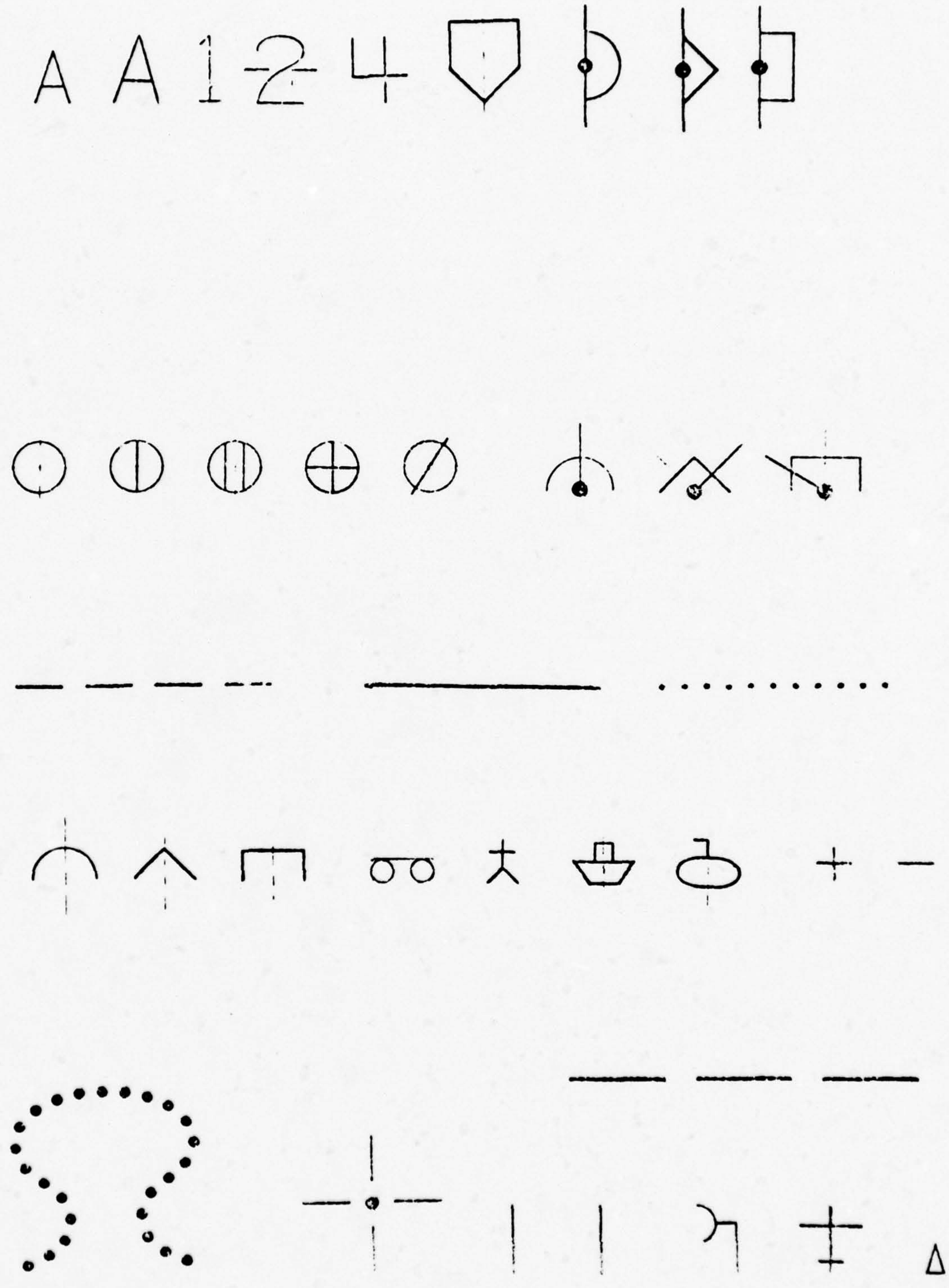
A stroke-generated symbol can be created by two different techniques. One technique is to turn the beam on at the beginning of its stroke and off at the end. The second technique is to chop the beam during its stroke generating closely spaced dots which appear as a continuous line at the viewing distance. Stroke-generated symbols do not have the problems associated with raster symbology; however, a pure stroke-generated display cannot display sensor video. Displays are being used that generate stroke symbology while at the same time displaying sensor video but the number of stroke symbols are limited. Thus, all of the envisioned symbols could not be displayed on the most complex presentation. The only pure raster display of a quality approaching stroke symbology is a prototype unit using: 50 frame/100 field rate, 2:1 interlace, with approximately 1000 TV scan lines.

The JTIDS display, therefore, should use stroke-generated symbology. If displayed sensor video is a requirement, then display sensor video only for that mode and JTIDS stroke symbology for the JTIDS mode. If a combination of both modes is required, then only selected JTIDS stroke symbols, determined by the priority list discussed further in Appendix C, (threat clutter/declutter) should be displayed. The symbol size and font selected necessitates the use of stroke generated symbology and would have to be re-evaluated and respecified if raster symbols are proposed. The complete SSC generated symbol set for JITDS flight test is found in Appendix C. A partial flight test symbol set is shown in Figure 2.

2. DISPLAY.

a. Contrast Ratio:

The contrast ratio (CR) shall be a minimum of 4:1 in 10,000 ft. lambert ambient light where contrast ratio is defined as:


A A 1 2 4

$$C.R. = \frac{Bs}{Bb} \qquad \begin{array}{l} Bs = \text{Symbol Brightness} \\ Bb = \text{Background Brightness} \end{array}$$

The minimum brightness of the symbol as viewed by the pilot, when achieving a C.R. of 4:1 in 10,000 ft. lamberts, shall be 150 ft. lamberts. The display brightness will be continuously variable from maximum to zero, with maximum angular control at the lower end. This requirement can easily be met using a bandpass filter matched to a P43 phosphor CRT.

b. Size:

The recommended display size for flight test shall be 5" horizontal X 7" vertical or larger with the lower two inches dedicated to alphanumeric readouts printed in columns and/or line text. The lower two inches shall be referred to as the text portion of the display. The minimum active CRT area shall be 4.6" horizontal times 6.6" vertical. It is recognized that some aircraft installations during the production/retrofit phase will require smaller displays; however, each type of installation should be individually evaluated by the SSC so that recommendations can be made on the quantity of symbology and the positioning of the text readout.

c. Location:

(1) Viewing Distance - The maximum expected viewing distance should influence the size of the details (symbols, alphanumerics) on the display. Many displays are designed for reading at arm's length in order to permit the operator (in a single place aircraft, the pilot) to reach switches or adjust knobs. This limit is generally set at 28 inches. The display controls preferably should be accessible to either hand.

(2) Viewing Angle - Viewing angles greater than 45^{o} shall be avoided. For console displays it is advisable to keep display slope under 30 degrees for the seated operator. The surface plane of the display shall be perpendicular to a line-of-sight emanating from designed eye $\pm 30^{o}$.

NOTE: In view of the upcoming F-15 flight test, the SSC recommends that the armament control set be combined with the JTIDS display.

d. Capability:

The display system shall be capable of displaying 500 symbols at one time. A symbol is defined as any alphanumeric or geometric symbol (e.g., vehicle, political boundary). Most symbols will remain upright to the pilot (e.g., vehicles, troops, air and land based threats, waypoints, etc.); however, a minimum of 30 vectors associated with the aircraft symbols will have 360° rotation capability and be displayed without aircraft movement across the map. When the aircraft symbol is fixed (e.g. self-centered), map movement occurs and certain symbols will have to be rotated (e.g., political boundaries, composite lethal radii, FEBA lines, train tracks, safe/unsafe areas, ground track, etc.). Thirty to forty circles will be displayed in addition to other symbology. Geometric symbols and alphanumerics can be written anywhere in the display and continuously moved (e.g., SAMs, AI data, etc.). The symbology refresh rate will be a minimum of 50 times a second. The symbology generation technique will be by calligraphic strokes. Data update rate for symbol positioning recommended by the SSC is 20 times per second or whatever the JTIDS net recycle time if update rate is greater than 20 times per second.

e. Resolution/Positional Placement:

The resolution/positional placement of symbols or data will be a minimum of $\frac{1}{1024}$ of display height or width (i.e., the height is divided into 1024 segments and width is divided into 1024 segments). This number is compatible with digital systems and is being used on some current aircraft displays.

f. Color:

When the task is a visual search for targets in a cluttered field of view, color coding of the symbols has an excellent application since it has been shown (Howell and Fuchs, 1961) that search times for the targets are reduced; however, the learning of the meaning of color codes requires more effort. Shapes combined with color permit the advantages of both to be used. The trade-offs between cost, target recognition, and identification times will be investigated during Phase II of the symbology study.

Color display technology does not permit a display with a high contrast ratio in sunlight, as with a single color display, and this may degrade performance overall. Color is not recommended for flight test, but will be considered during Phase II for technology changes in contrast capabilities.

g. Clutter/Declutter:

Due to the number of symbols that can be displayed on the situational portion of the display, switches/push buttons will be required to manually add or delete selected symbology from the normal mode using a display menu-technique. Further discussion is included in System Recommendations (4.a and 4.b).

3. OPERATOR WORKLOAD.

The system must not overload the operator using it. Perhaps there will be operators whose full-time job is to monitor and extract information from the display, but initially only a pilot in a single seat aircraft will be the operator. Because the pilot's prime task is maintaining aircraft control and safe effective mission accomplishment, he must be able to extract information from the display rapidly and accurately. The initial design of the system will be discussed from the standpoint of the pilot of the single seat aircraft.

a. Monitoring Task Loading:

Because no mock-ups or specific cockpit studies were used as part of this exercise, estimates of the workload were not made. Certain general comments can be made about the total workload. Workload will be a function of the maneuver, the amount of information to be displayed, the time available to scan the display, and the ability of the human to manipulate the controls. Some maneuvers demand the full concentration of the pilot and allow no time to look at a display, e.g., final stages of an air-to-air engagement.

The information displayed may or may not pertain to the mission to any great extent. The information on the display could undoubtedly be too great in quantity for some users; therefore, it is assumed that some means will exist for the pilot to declutter the display.

The pilot has other tasks such as navigation, communications, weapon delivery, IFF codes, etc., that will undoubtedly interact with monitoring performance of the display. Without cockpit simulation, there is no way to predict what effect, if any, these tasks will have upon display monitoring. Simulation is planned for Phase II of this study.

b. Pilot Eye Scan Patterns:

It may be assumed that the pilot of a single seat aircraft will have little time to devote to the display. When a pilot is flying VFR it is estimated that 75 to 80 percent of the visual scan pattern will be out of the cockpit. Conversely under IFR, primary attention is inside the cockpit. Studies (Crawford et al, 1976) indicate that a keyboard operation with an associated CRT display can be carried on simultaneously with an instrument flight task and there will exist only a slight non-significant loss in performance on both tasks. In this experiment, monitoring duties were divided between the CRT display and the flight director.

Data from other studies (Reference 2) indicate that for single seat aircraft, the pilot will have from one to five seconds to be alerted to a threat, identify the threat and to ascertain its position and azimuth of the threat. Pilots will have forewarning of some threats (e.g., SAM, AAA, etc.), but some will appear suddenly (e.g., enemy interceptors and unknown SAM and AAA). The one to five seconds observation time will apply in this situation.

The range in nautical miles represented on the display interacts with the operator workload. More symbols are likely to be present on a display with a larger range in nautical miles reflected. The range represented by the display should be variable by the pilot and options should vary from two and one-half to two hundred miles.

c. Reaction Time Requirements:

Response times and control operation times determine the amount of information which can be displayed. Tabled response times (Morgan et al, 1963) show the pilot requires 0.9 seconds to move his eyes to a specific object on a display, focus, and interpret the image. If he selects a course of action, another 0.8 seconds is required to carry it out. This results in a total of 1.7 seconds on the average. If there exist several choices of action, the choice reaction time increases to about 0.6 seconds for one to ten symbols. An optimistic estimate of the maximum number of symbols which should appear on the display in stress situations is ten. Another study (Emory & Strother, 1970) examining the performance of TAC pilots on an RWS display bears this out.

The SSC recommends the use of a designator symbol which would allow the operator to extract expanded information regarding that symbol. This special symbol will be moved by a control device. If the pilot must move the special symbol 2.75 inches (~1/2 the diameter of the display) on the average, it is estimated (Table 1) that it would take him four seconds to move the special symbol within one-tenth inch accuracy of a designated spot 2.75 inches from the special symbol. The pilot will not be able to designate more than one symbol in five seconds.

Obviously some prioritizing of importance of threats must take place. The information for the pilot to use to make this determination must be immediately available and has been judged to be the type threat and state of that threat. This information should be totally available on the decluttered display.

d. Aircrew Participation:

The pilot can use a number of methods for transmitting data to and receiving data from the JTIDS net. These are discussed below.

TABLE I

ERROR (DISTANCE TO MOVE CURSOR VERSUS TIME)*

Time (Seconds)	0.5	2.0	5.0 Distance (Inches) to Move Cursor
0.75	0.52	2.10	4.77
1.68	0.29	1.40	4.12
2.85	0.10	0.73	1.21
4.0	0.05	0.05	0.73

Example:

Given -

Distance to move cursor = 2.0 inches

Time available for task = 2.85 seconds

then, Error (average distance between target track and cursor) = 0.73 inches.

*Data from Pearson and Crawford, 1972, Unpublished.

(1) Transmission Methods:

(a) Automatic - Transmitted by on-board equipment without any pilot action [e.g., Identification, Friend or Foe (IFF)/Selective Identification Feature (SIF)].

(b) Manual - Requires pilot actions for transmissions (e.g. pilot selective options require coding and/or display).

(c) Voice - Primary method of communicating aircraft status, mission essential information, etc.

NOTE: Due to the present voice load, automatic transmission for JTIDS shall be maximized.

(2) Reception Methods:

(a) Audio - With the exception of electronic warning [e.g., Radar Homing and Warning (RHAW)], and navigation information tones, all other external cockpit information on data link equipped aircraft is received through the voice channel. It goes without saying that any further information cannot be tolerated using voice.

(b) Visual - Radar/Electro-Optical (EO) and RHAW displays are the present means by which a pilot receives information external to his cockpit.

(c) Automatic - Received by on-board equipment without any pilot action (e.g., data link, JTIDS, etc.).

NOTE: Due to the present audio load on the pilot, JTIDS automatic reception of information should be processed and visually displayed to the maximum extent possible.

4. SYSTEM RECOMMENDATIONS.

Now that all the symbols have been designed, the pilot must interact with them to operate JTIDS in the cockpit. The pilot, unfortunately, suffers from an "embarrassment of riches" as far as information is concerned. The JTIDS net is capable of presenting numerous bits of information on the display which can quickly overwhelm the pilot's ability to process information; therefore, a declutter scheme must be discussed for

the removal of symbology, and a prioritization algorithm must be devised for the symbology which remains after declutter has occurred. Each of these concepts will now be discussed.

a. Display Declutter:

As stated in III.2-g (Clutter/Declutter), declutter switches/push buttons will be mounted on the bezel of the JTIDS display. If it is a push button, it will be a push-push type in which the first push of the switch removes symbology from the display and a second push of the switch restores the symbology. The type of symbology that could be removed by the activation of the declutter switch is all non-threat symbology (e.g., friendly aircraft, ground track, waypoints, safe areas, alphanumeric map messages, but not the text portion, etc.). The threat symbology remaining will consist of hostile aircraft, SAMs, and AAA.

b. Threat Clutter/Declutter (Classified):

See Appendix C.

5. ABBREVIATIONS.

Alphanumeric messages will play a major role in supplying and extracting information to and from the JTIDS net.

The symbol which is the subject of the information may or may not be on the CRT display. If the symbol is within the display's selected field-of-view, a cursor may be positioned over the symbol to designate/indicate it as the symbol about which information is desired. If the symbol is not on the display at the time information is desired, then some identifying designation must be assigned to withdraw information from the system. Either way the majority of the information will be in some form of alphanumerics.

The alphanumerics messages will generally be abbreviated. To standardize on a technique for generating the alphanumeric abbreviations, the initial test should use MIL-STD-783. If a word or word group is not found in MIL-STD-783, then use the program contained in the draft report Reference 3, "Design Procedure for Allocating Panel Area for Aircrew Stations Using Information Transfer - CUBITS". The program will be followed closely as possible in generating the abbreviations with the realizations that

certain abbreviations (e.g., A/S for airspeed) will be exceptions to the program. When these exceptions occur, the SSC will review the proposed exceptions for approval and possible inclusion in the MIL-STD.

Double (4 pages)
May not need to photograph

$$C.R. = \frac{Bs}{Bb}$$

Bs = Symbol Brightness
Bb = Background Brightness

The minimum brightness of the symbol as viewed by the pilot, when achieving a C.R. of 4:1 in 10,000 ft. lamberts, shall be 150 ft. lamberts. The display brightness will be continuously variable from maximum to zero, with maximum angular control at the lower end. This requirement can easily be met using a bandpass filter matched to a P43 phosphor CRT.

b. Size:

The recommended display size for flight test shall be 5" horizontal X 7" vertical or larger with the lower two inches dedicated to alphanumeric readouts printed in columns and/or line text. The lower two inches shall be referred to as the text portion of the display. The minimum active CRT area shall be 4.6" horizontal times 6.6" vertical. It is recognized that some aircraft installations during the production/ retrofit phase will require smaller displays; however, each type of installation should be individually evaluated by the SSC so that recommendations can be made on the quantity of symbology and the positioning of the text readout.

c. Location:

(1) Viewing Distance - The maximum expected viewing distance should influence the size of the details (symbols, alphanumerics) on the display. Many displays are designed for reading at arm's length in order to permit the operator (in a single place aircraft, the pilot) to reach switches or adjust knobs. This limit is generally set at 28 inches. The display controls preferably should be accessible to either hand.

(2) Viewing Angle - Viewing angles greater than 45° shall be avoided. For console displays it is advisable to keep display slope under 30 degrees for the seated operator. The surface plane of the display shall be perpendicular to a line-of-sight emanating from designed eye $\pm 30^{\circ}$.

NOTE: In view of the upcoming F-15 flight test, the SSC recommends that the armament control set be combined with the JTIDS display.

d. Capability:

The display system shall be capable of displaying 500 symbols at one time. A symbol is defined as any alphanumeric or geometric symbol (e.g., vehicle, political boundary). Most symbols will remain upright to the pilot (e.g., vehicles, troops, air and land based threats, waypoints, etc.); however, a minimum of 30 vectors associated with the aircraft symbols will have 360° rotation capability and be displayed without aircraft movement across the map. When the aircraft symbol is fixed (e.g. self-centered), map movement occurs and certain symbols will have to be rotated (e.g., political boundaries, composite lethal radii, FEBA lines, train tracks, safe/unsafe areas, ground track, etc.). Thirty to forty circles will be displayed in addition to other symbology. Geometric symbols and alphanumerics can be written anywhere in the display and continuously moved (e.g., SAMs, AI data, etc.). The symbology refresh rate will be a minimum of 50 times a second. The symbology generation technique will be by calligraphic strokes. Data update rate for symbol positioning recommended by the SSC is 20 times per second or whatever the JTIDS net recycle time if update rate is greater than 20 times per second.

e. Resolution/Positional Placement:

The resolution/positional placement of symbols or data will be a minimum of $\frac{1}{1024}$ of display height or width (i.e., the height is divided into 1024 segments and width is divided into 1024 segments). This number is compatible with digital systems and is being used on some current aircraft displays.

f. Color:

When the task is a visual search for targets in a cluttered field of view, color coding of the symbols has an excellent application since it has been shown (Howell and Fuchs, 1961) that search times for the targets are reduced; however, the learning of the meaning of color codes requires more effort. Shapes combined with color permit the advantages of both to be used. The trade-offs between cost, target recognition, and identification times will be investigated during Phase II of the symbology study.

SECTION IV

RECOMMENDATIONS

This section is a compilation of SSC recommendations found in previous sections of this document.

The SSC recommends:

1. NAMEL font for the alphanumeric on the JTIDS display.
2. The largest dimension of a symbol be no less than 17 minutes of visual angle.
3. An aspect ration of 3:2, height to width.
4. Display should use stroke-generated symbology.
5. Contrast ratio shall be a minimum of 4:1 in 10,000 ft. lambert ambient light.
6. Minimum brightness of the symbol as viewed by the pilot, when achieving a C.R. of 4:1 in 10,000 ft. lamberts, shall be 150 ft. lamberts.
7. Display size for flight test shall be 5" horizontal x 7" vertical or larger with the lower two inches dedicated to alphanumeric readouts printed in columns and/or line text.
8. Display controls preferably should be accessible to either hand.
9. Viewing angles greater than 45° shall be avoided.
10. For an F-15 flight test, combine the armament control set with the JTIDS display.
11. Data update rate for symbol positioning shall be a minimum of 20 times per second. Symbol refresh rate will be a minimum of 50 times a second.
12. Color not be used for flight test.
13. A designator symbol used to extract expanded information regarding the symbol.
14. Use alphanumeric abbreviation generating technique contained in MIL-STD-783. For word or word groups not contained in MIL-STD-783 use the program contained in the Draft Report, "Design Procedure for Allocating Panel Area for Aircrew Stations Using Information Transfer - CUBITS."

SECTION V

FOLLOW-ON RECOMMENDATIONS

During the course of the Phase I Study, numerous questions and problems arose which need to be addressed and solved. Due to the short time frame involved in the Phase I effort, no experimental research could be conducted to address these issues. Some of the problems requiring investigation in Phase II Study are:

1. Color coding of symbols to optimize operator/system performance.
2. Investigate the confusion of symbols both within a symbol set and between symbol sets.
3. Population stereotypes of symbol construction.
4. Investigate the interpretation and dynamics of the symbol set derived in Phase I.
5. Clutter as a function of symbol size and display density.
6. Removal of the menu cueing information from the situation display area. Reference 4,Information Presentation and Control Concept for JTIDS in a Single Seat Tactical Aircraft - Part II: Implementation and Data Management.

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7. Display size for flight test shall be 5" horizontal x 7" vertical or larger with the lower two inches dedicated to alphanumeric readouts printed in columns and/or line text.
8. Display controls preferably should be accessible to either hand.
9. Viewing angles greater than 45^{o} shall be avoided.
10. For an F-15 flight test, combine the armament control set with the JTIDS display.
11. Data update rate for symbol positioning shall be a minimum of 20 times per second. Symbol refresh rate will be a minimum of 50 times a second.
12. Color not be used for flight test.
13. A designator symbol used to extract expanded information regarding the symbol.
14. Use alphanumeric abbreviation generating technique contained in MIL-STD-783. For word or word groups not contained in MIL-STD-783 use the program contained in the Draft Report, "Design Procedure for Allocating Panel Area for Aircrew Stations Using Information Transfer - CUBITS."

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SECTION VI

CONCLUSION

With the short lead time allowed to complete a task of this nature, the data base that was collected and reviewed was more than adequate to generate the symbol set for the JTIDS flight test. Much work remains to be accomplished before the SSC can complete a final operational set of symbols. That will be accomplished in Phase II of the JTIDS symbology standardization. The SSC is confident that by the time the production symbol set is evolved, many of the unanswered questions that have arisen through the meetings leading up to this document will be answered through simulation and the JTIDS flight test.

This report completes Phase I of the JTIDS symbology standardization efforts.

APPENDIX A

SURVEYED ORGANIZATIONS

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ATTN: Mr. John Erickson, Director
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ATTN: Ron Erickson
China Lake CA 93555

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APPENDIX B

DOCUMENTS SURVEYED

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